

Climate Risks in the Commercial Mortgage Portfolios of Life Insurers: A Focus on Sea Level Rise and Flood Risks

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IMPORTANCE Commercial mortgages are an important asset class of life insurers. Approximately 15% of the life insurance industry asset is held in commercial mortgages. Life insurers are also important institutional investors in the commercial real estate (CRE) market. They hold approximately 14% of the outstanding CRE mortgage loans and are the third-largest institutional lenders in the U.S. commercial mortgage market. Life insurers are exposed to both physical and transitional risks of climate change through their commercial mortgage investments. Physical damages to commercial properties may increase due to flooding or SLR, and the devaluation of certain commercial properties as the economy transitions can also lead to financial losses for life insurers.

OBJECTIVES In this paper, we explore the climate risk exposure of U.S. life insurers' commercial mortgage loan portfolios, focusing on SLR and flood risks. We also examine the effect of regulatory reforms related to commercial mortgage holdings in the U.S. life insurance industry to understand the link between climate change risk and regulations.

FINDINGS From 2012 to 2019, we find that the size of newly issued commercial mortgages by life insurers in the U.S. grew from \$37 billion to \$56 billion (by 51%). This growth exceeded that of total assets, which grew by 28% during the period. The average loan value is \$9 million, and the average loan-to-property value ratio is 58%. Many commercial mortgages are issued for properties in coastal areas. Yet, few properties are located in low-lying coastal areas. Over time, we find an increasing share of multi-family buildings within new mortgages from 20% to 41% and a decreasing share of retail buildings from 34% to 13%. The share of office buildings has also decreased from 28% to 22% but not as significantly as retail buildings. We find heterogeneity across life insurers in terms of the average loan size, the loan origination frequency, as well as loan locations. In terms of locations, life insurers tend to originate loans in metropolitan areas, many of which are on the coast. Some life insurers focus on specific geographical areas that happen to be exposed to high levels of SLR or flood risks (e.g., Florida), while some diversify across metropolitan areas (coastal or noncoastal) in the U.S. Descriptively, we find no significant drop in life insurers' exposure to SLR risk or flood risk after the regulatory reforms.

CONCLUSION AND RELEVANCE While vast literature and industry reports document the potential impact of climate change on the insurance industry, most focus on the property insurance market. Life insurers hold a significant number of commercial mortgages, which are prone to both physical and transitional risks of climate change and are much less researched or understood. We examine the climate risk exposure of commercial mortgage portfolios among life insurers, as well as its interaction with

regulatory reforms. Our findings have important policy implications for regulators and researchers. For a more rigorous examination of whether life insurers changed their underwriting standards due to the reforms, regulators and researchers would need data on the granular street-level addresses of the commercial properties and financial characteristics of the properties.

Climate Risks in the Commercial Mortgage Portfolios of Life Insurers: A Focus on Sea Level Rise and Flood Risks*

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ABSTRACT

In this paper, we explore the climate risk exposure of U.S. life insurers' commercial mortgage loan portfolios, focusing on sea level rise (SLR) and flood risks. While vast literature and industry reports document the potential impact of climate change on the insurance industry, most focus on the property insurance market. Life insurers hold a significant number of commercial mortgages, representing approximately 15% of their assets by the end of 2021. These investments are susceptible to both physical and transitional risks of climate change and are much less researched or understood. From 2012 to 2019, we find that the size of newly issued commercial mortgages by life insurers in the U.S. grew from \$37 billion to \$56 billion (by 51%). We find heterogeneity across life insurers in terms of the average loan size, the loan origination frequency, as well as loan locations. In terms of locations, life insurers tend to originate loans in metropolitan areas, many of which are on the coast. Some life insurers focus on specific geographical areas that happen to be exposed to high levels of SLR or flood risks (e.g., Florida), while some diversify across metropolitan areas (coastal or noncoastal) in the U.S. Our findings have important policy implications for regulators and researchers.

Keywords: commercial real estate, sea level rise (SLR), flooding, life insurers, mortgage loan

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1. Introduction

Insurers are exposed to both physical risk and transitional risk of climate change, as they play critical roles in underwriting, as well as financing coastal properties (i.e., through mortgage lending). Although insurers can mitigate physical risks associated with climate change by revising underwriting standards upon renewing insurance contracts, the effect of transitional risk on their assets is less clear as many insurers invest in long-term illiquid assets.

Flooding is one of the most ubiquitous natural disasters in the U.S., and its impact may be exacerbated by climate change, coastal buildup, or sea level rise (SLR). SLR is one of the most salient and quantifiable long-run climate change risks today.¹ In markets involving sophisticated investors or buyers, even if SLR-induced inundation does not happen in 10 or 30 years, economic damages may occur because of the uncertainty and the forward-looking nature of market participants. Today, life insurers, along with banks and commercial mortgage-backed securities (CMBS) lenders, originate the vast majority of commercial real estate (CRE) loans (Glancy et al., 2022). A high percentage of insurers' CRE lending is concentrated in the 20 to 30 largest metropolitan areas in the country (Davis, 2018).² Our calculation suggests that 45% of loan values originated by life insurers in 2019 are located in areas within 30 kilometers of the coast, which expose life insurers to potentially significant physical and transitional risks from climate change.

In this paper, we study life insurers' commercial mortgage portfolios and the insurer-level exposure to SLR and flood risks. We first analyze the geographic distribution of their CRE loans, using detailed loan-level information on their mortgages from their statutory filings from 2012 to 2019. Then, we merge loan-level geographical information (ZIP code) with scientific measures of SLR risk and flood risk, as well as the Federal Emergency Management Agency's (FEMA's) Special Flood Hazard Area (SFHA) information. We find geographical heterogeneity in life insurers' holdings of CRE loans, as well as variations across insurers in terms of SLR and flood risk exposure in their mortgage lending portfolios. We then introduce two regulatory reforms: the Biggert-Waters Flood Insurance Reform Act of 2012 (BW-12) on flood insurance premiums and insurers' commercial mortgage risk-based capital (RBC) requirement reform. Both reforms went into effect at the end of 2013, which could affect life insurers' decisions to finance commercial properties, especially in areas exposed to SLR or flood risks.

Our analysis can inform insurance regulators, insurance companies, and insurance consumers. Life insurance companies' mortgage financing decisions affect the financial market, as they are one of the main institutional investors in the commercial mortgage market. Insurers' risk exposures in their mortgage portfolios affect their operating

1. The upper bound projections of the global-mean SLR level have been increasing, with recent projections of up to 2.5 meters (more than six feet) by the year 2100 (DeConto & Pollard, 2016; Garner et al., 2018; Goldsmith-Pinkham et al., 2023; Slater et al., 2021; Sweet et al., 2017). That projection can put nearly 2.5 million properties in the U.S.—valued at more than \$1 trillion—at risk of chronic inundation by the turn of the century (Dahl et al., 2017).

2. Ten out of the top 20 largest metropolitan areas are along the coastline or bay and could be directly impacted by SLR, such as New York-Newark-Jersey City and Miami-Fort Lauderdale-Pompano Beach. Besides those along the coastline or bay, many of the other largest metropolitan areas are along rivers, such as Washington-Arlington-Alexandria.

profit, as well as solvency risk, which can directly impact policyholders. In particular, our analysis sheds light on future regulatory frameworks to estimate and quantify insurance companies' exposure to climate change risk, especially to SLR risk and flood risk. More broadly speaking, our paper contributes to the literature on how long-run risks, such as climate change, are internalized in the real estate market. For example, Baldauf et al. (2020) emphasize the effect of heterogeneous beliefs on future climate risk in the residential real estate market. Addoum and Eichholtz (2021) find that flood risk is capitalized in CRE markets and that the revised valuation after Hurricane Sandy reflects a persistent shift in risk perception. In contrast to prior studies, we focus on a unique group of financial market participants—life insurers—who provide long-term mortgages to the CRE market and who are potentially sensitive to SLR and flood risks.

Our paper also contributes to the literature examining insurers as important institutional investors. Insurers' portfolio choices could materially impact the price of risk in the economy (e.g., Hufeld et al., 2017; Chodorow-Reich et al., 2021). To our knowledge, we are the first to examine if insurers' portfolio choices are influenced by SLR risks. In a related paper, Ilhan (2021) examines household portfolio choices and treats SLR as a source of undiversifiable background risk. He finds that SLR-exposed homeowners are less likely to participate in the stock market, and they invest a smaller share of their financial wealth in risky assets. In comparison to households, insurers are sophisticated and well-diversified institutional investors. Insurers are also sensitive to regulatory capital requirements in their investments.³ Our findings, therefore, can provide transparency to regulators and market participants about insurers' investment exposure to climate change.

Lastly, our paper contributes to the understanding of the role of the insurance and mortgage industries in facilitating risk-sharing and extending credit to individuals and businesses in the climate change adaptation process. Most existing literature focuses on the residential market. For example, Ouazad and Kahn (2022) document that residential mortgage lenders transfer climate risk to government-sponsored enterprises (GSEs) after extremely damaging hurricanes, which changes the optimal number of mortgages that should be originated. They suggest that the ability to securitize the GSEs may have weakened the discipline brought about by the mortgage industry in fostering climate change adaptation.⁴ In comparison, when insurers act as CRE lenders, they most likely hold those mortgages to maturity in their portfolio. On the one hand, the inability to pass on the risk to another entity (e.g., the government) should lead to more careful underwriting of the risk. On the other hand, the very long-term nature of climate change-related risks provides a test of the private industry's ability and willingness to act in the best interest of all stakeholders in the long run.

The rest of the paper is organized as follows. Section 2 gives an overview of the commercial mortgage lending practices of U.S. life insurers, including past and pres-

3. Insurers' investment decisions are significantly influenced by capital requirement regulations (Becker & Ivashina, 2015; Becker et al., 2022; Ellul et al., 2015; Ghent et al., 2019; Glancy et al., 2022; Hanley et al., 2018).

4. An analogy of moral hazard in the insurance underwriting business can be found in the National Flood Insurance Program (NFIP). Cordes and Yezer (1998) find that participation in the initial "Emergency" phase of the NFIP increased single-family housing permits by around 50%, providing evidence that a public insurance program significantly distorts housing development incentives. A more recent study by Browne, Dehring, Eckles, and Lastrapes (2019) on the same topic find more nuanced results: the effects of participating in NFIP on housing development are different among coastal communities versus non-coastal communities.

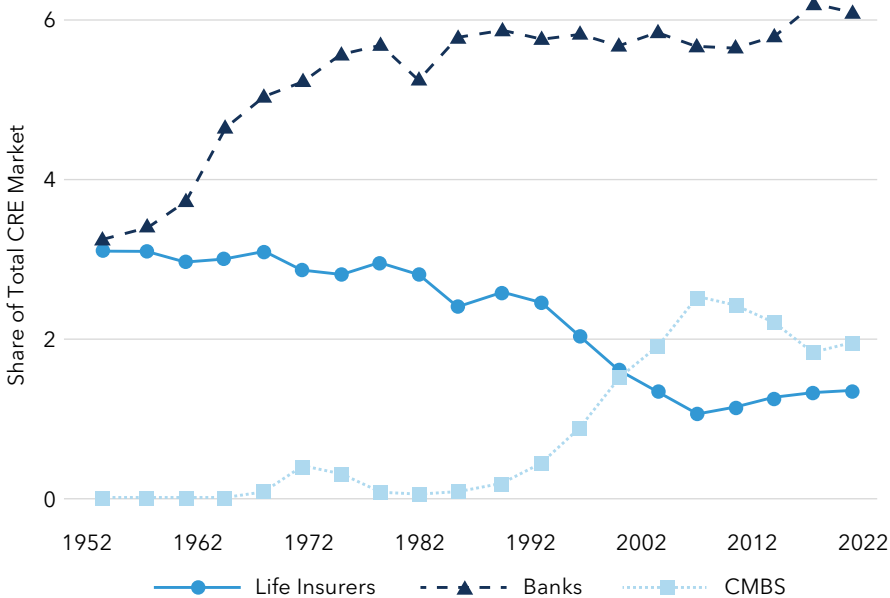
ent institutional background, summary statistics on mortgage loans, property, and insure-level characteristics, especially relating to their exposure to SLR and flood risks. Section 2 also provides case studies on a few insurers most exposed to SLR risk. Section 3 introduces two regulatory reforms and analyzes their possible impacts on life insurers’ mortgage lending activities. Section 4 concludes with a discussion of regulatory implications.

2. Commercial Mortgage Lending of Life Insurers

2. 1. Institutional Background

Mortgages are traditional asset items on life insurers’ balance sheets. The long-term nature of mortgages matches well with the long-term liability structure of life insurance companies. According to the 1913 Insurance Year Book, 34.7% of life insurer assets were in real-estate mortgages (Huebner, 1919). With the evolution of the capital markets, such as the savings and loan crisis in the 1980s and the rise of competition from CMBS beginning in the early 1990s (e.g., Glancy et al., 2022; Riddiough, 2000; Titman & Tsyplakov, 2010), life insurers reduced their mortgage holdings to around 15% by the end of 2021—still a significant share of their assets—with the majority of them in commercial real estate (NAIC, 2021). During the same time period, although life insurers have reduced their influence in the U.S. commercial mortgage market, they remain one of the main institutional investors, taking up approximately 14% of all outstanding commercial mortgages by the end of 2021 (MBA, 2022). In Figure 1, we show the lender shares of the U.S. commercial mortgage market from 1952 to 2022 for life insurers, banks, and CMBS.

Figure 1: U.S. Commercial Real Estate by Lender



Note: The data come from the Financial Accounts of the United States Z.1 Statistical Release data (Release date March 2023). The sum of life insurers, banks, and CMBS shares do not sum to 100% because there are other commercial real estate lenders such as government entities and non-financial firms.

Insurance companies are sophisticated institutional investors who have the ability and reason to price long-run risks, such as climate change-related risks. Perhaps more than other types of investors in the mortgage market, life insurers conduct thorough due diligence when underwriting commercial mortgages.⁵ Compared to banks, life insurers focus more on fixed-rate, large-sized, and long-duration loans (Davis, 2018; Glancy et al., 2022). They also prefer non-recourse, large-sized loans for which the lender can only repossess the property but not sue the borrower for any personal liability. There is no restriction as to where a life insurer can originate commercial mortgages, and typically, life insurers work with mortgage brokers around the nation to identify investment opportunities (Snowden, 1995). Consequently, the physical and economic environment where the property is located should matter, which may be influenced by climate change risks.⁶ Alternatively, life insurers may not take into account climate change risk due to their financial strength and a well-diversified investment portfolio or by filtering out the most vulnerable properties in their stringent underwriting.

2.2. Data and Summary Statistics

Using the statutory financial statements filed by life insurers, we document the characteristics of commercial mortgages (loans) held by life insurers. We focus on new fixed-rate commercial mortgage loans originated by active stock or mutual life insurers with positive invested assets in any given year with detailed property information, such as property type and location (ZIP-code level).⁷ The majority of loans originated by life insurers (approximately 90%) are fixed-rate loans. This is different from banks, which frequently issue floating-rate loans (Glancy et al., 2022). To identify geographic information, such as the ZIP code of the property, we exclude loans located in multiple ZIP codes (approximately 5% of the sample). We exclude loans with potential reporting errors, such as negative loan or property values, and exclude insurers that originate less than three loans in total over the sample period.⁸ We then construct a loan-insurer-year level dataset from 2012 to 2019.⁹ For detailed construction of the dataset, refer to Appendix A.

In Table 1, Panel A, we show mortgage-level summary statistics of interest rate spread, loan term, loan value, property value, loan-to-value ratio, property type, and whether the property is located in the state of the insurer's domiciliary or the state where the main office of the insurer is located. On average, life insurers issue loans

5. We learned many details described in this paragraph from conversations with Steven Bardzik, a staff at the NAIC and a commercial mortgage broker with life insurer clients.

6. When underwriting commercial mortgages, life insurers pay much attention to the loan-to-value (LTV) ratio and the debt service coverage (DSC) ratio, both of which are subject to regulatory scrutiny. A depreciation in property value or a decrease in future business income due to climate risk exposure can lead to a higher LTV ratio or a lower DSC ratio, thereby making the loan riskier.

7. Active life insurers are those without any regulatory action in the process. We identify mutual and stock insurers (including private stock insurers) from the statutory statements.

8. We chose the threshold of three based on the distribution of the number of mortgages originated over the sample period, as shown in Appendix B. We observe a sharp drop in the distribution of the total number of mortgages over the sample period from two to three, followed by a monotonic distribution for insurers with three or more total mortgages. This procedure drops 33 unique insurers (holding 52 loans) out of 259 unique insurers holding at least one sample loan.

9. The detailed geographical information at the ZIP-code level was first required in the statutory financial statements in 2014. We impute the ZIP-code level information for new loans originated from 2012 to 2014 using the mortgage holdings data following Glancy et al. (2022).

with 2.17 interest rate spreads, which is the difference between the interest rate and risk-free rates.¹⁰ The average loan term is 14.7 years, and the interquartile range lies between 10 to 20 years. The average loan value is \$9.22 million, and the median value is \$3.2 million, suggesting the presence of large-value loans. The average property value is \$18 million, and the loan-to-value ratio is 0.58 on average.

Table 1: Summary Statistics

	Obs	Mean	SD	1st	25th	50th	75th	99th
A: Loan and Property								
<i>Spread</i>	42,913	2.17	1.08	0.64	1.61	2.00	2.45	6.62
<i>Loan Value (Mil.)</i>	42,913	9.22	20.10	0.02	0.97	3.20	9.00	98.90
<i>Property Value (Mil.)</i>	42,913	18.14	44.27	0.04	1.68	6.05	17.00	196.40
<i>Loan-to-value ratio</i>	42,913	0.58	0.16	0.09	0.50	0.61	0.69	0.86
<i>Term (years)</i>	42,913	14.73	7.27	2.01	10.02	12.59	20.05	30.09
<i>In State of Domi.</i>	42,913	0.05	0.21	0.00	0.00	0.00	0.00	1.00
<i>In Office State</i>	42,913	0.05	0.22	0.00	0.00	0.00	0.00	1.00
B: Zipcode Geographic								
<i>I(SLR 20 %)</i>	42,913	0.04	0.20	0.00	0.00	0.00	0.00	1.00
<i>SLR (%)</i>	42,913	2.75	10.42	0.00	0.00	0.00	0.00	63.89
<i>I(< 30km from Coast)</i>	42,913	0.34	0.47	0.00	0.00	0.00	1.00	1.00
<i>Distance to coast (km)</i>	42,913	306.08	367.55	0.40	15.47	108.20	493.74	1219.96
<i>Elevation (m)</i>	42,913	245.32	362.36	5.00	35.00	153.00	273.00	1705.00
<i>I(Flood Zone)</i>	42,913	0.17	0.38	0.00	0.00	0.00	0.00	1.00
<i>Flood Zone (%)</i>	42,913	11.61	14.36	0.00	2.56	7.03	14.50	69.76
<i>I(Flood Cup)</i>	7,321	0.19	0.39	0.00	0.00	0.00	0.00	1.00
<i>I(Avg. Flood Factor >3)</i>	42,913	0.08	0.28	0.00	0.00	0.00	0.00	1.00
<i>Avg. Flood Factor</i>	42,913	1.85	0.98	1.06	1.33	1.54	1.97	6.57
<i>I(Hurricanes past 9 qtr)</i>	42,913	0.02	0.14	0.00	0.00	0.00	0.00	1.00
Observations	42,913							

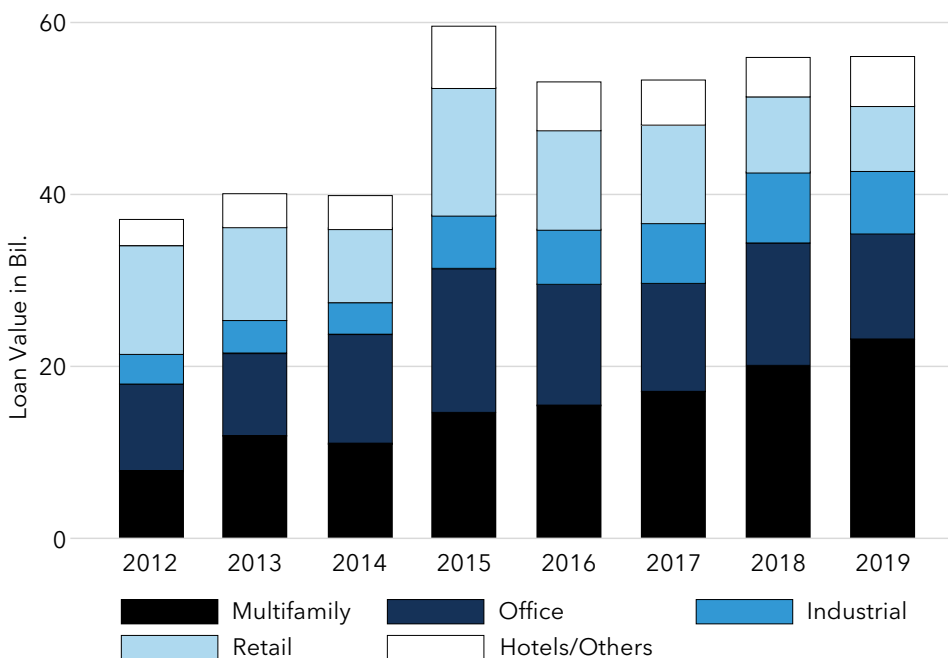
Note: The table reports summary statistics of loan-level variables. *Spread* is the difference between the mortgage interest rate and the rate on the U.S Treasury bond constant maturity yields with the same (or longer) maturity as the mortgage (2, 3, 5, 7, 10, 20, or 30 years), observed on the mortgage origination date. *Loan Value* is the size of the loan at the time of origination, *Property Value* is the size of the land or building of the loan at the time of origination, *Loan-to-value ratio* is the ratio between the *Loan Value* and the *Property Value*, and *Term (years)* is the number of years between the origination date to the maturity date of a loan. *In State of Domi.* is an indicator that the loan is located in the same state as the insurer's domiciliary state, and *In Office State* is an indicator that the loan is located in the same state as the insurer's main office state. *I(SLR 20%)* is an indicator for loans in a zip code area with more than 20% of its area inundated under the six-foot SLR scenario by 2100, and *SLR (%)* is the percent of the zip code area inundated under such SLR scenario. *I(<30km from Coast)* is an indicator for loans in a zip code within 30km from the coast, and *Distance to coast* is measured in km at the zip code centroid, while *Elevation* is measured in meters at the zip code centroid. *I(Flood Zone)* is an indicator for loans in a zip code area with more than 20% of its area designated as Special Flood Hazard Areas (SFHAs), *Flood Zone (%)* is the percent of the zip code area designated as SFHAs, and *I(Flood Cap)* is an indicator for loans with values under \$500,000 when located in an SFHA. *I(Avg. Flood Factor > 3)* is an indicator for loans located in a zip code with an average

10. We measure interest rate spreads as the difference between the loan interest rate and risk-free rate from Treasury bills (T-bills) with similar terms. For example, spreads for mortgages with less than a one-year term are calculated as the difference between the interest rate and one-year T-bill rate, and spreads for those with at least one year but less than a two-year term is the difference between the interest rate and two-year T-bill rate. For loans with terms exceeding 20 years, we use the 30-year T-bill rates. Risk-free rates are available for one-, two-, three-, five-, 10-, 20-, and 30-year terms.

flood factor larger than 3. *I(Hurricane past 9 qtr)* is an indicator for loans in a zip code that has been exposed to major hurricanes in the past nine quarters.

Life insurers originate mortgages for a diverse set of commercial properties. In Figure 2, we show the breakdown of property types by year. The main types of properties life insurers have commercial loan exposures on are multi-family, office, retail, and industrial properties. The “Hotels/Others” property category in the figure includes hotels and specialty commercial properties, such as medical buildings. The figure shows that although the composition is generally stable over our sample period, in recent years, the shares of multi-family and industrial loans have increased, and retail loans have decreased. This investment trend by life insurers reflects the overall real estate market conditions and investor sentiments. According to industry surveys and reports (PwC and the Urban Land Institute, 2023), the multi-family and industrial sectors have ranked at or near the top of real estate investment prospects going back to before the financial crises of 2008-2009, and the margin of preference for them over other property types has been increasing steadily. On the other hand, retail and office remain out of favor with real estate investors. The rise of e-commerce contributed to a shift in demand from retail to industrial space (such as warehouses). The rise in multi-family homes can be attributed to changing household demographics and an embrace of apartment development by the investment community.

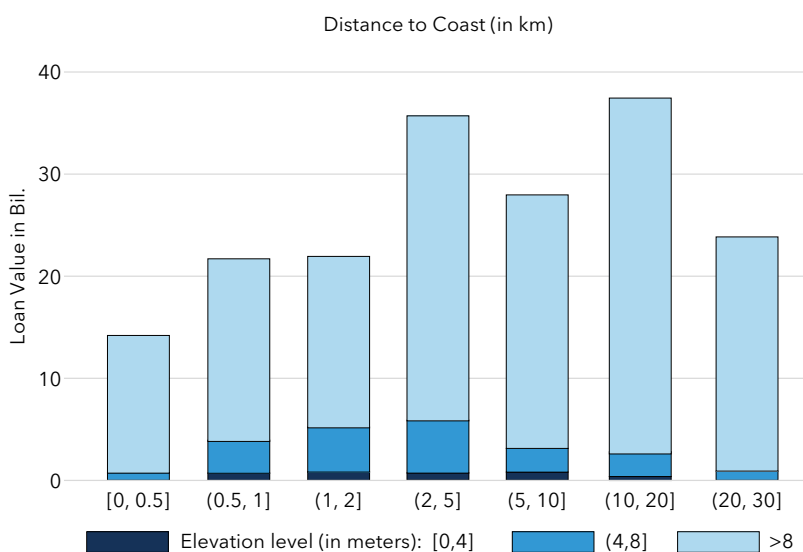
Figure 2: Commercial Property Types



Note: The figure shows the value of loans originated by life insurers in each year, separately for different types of properties.

In Table 1, Panel B, we show the geographic characteristics of the properties underlying the mortgages. Since our data only identify the ZIP code of the properties, all geographic characteristics are at the ZIP-code level. Only 5% of loans are located in the state of the insurer's domiciliary or the state of the insurer's main office. We construct ZIP-code level SLR risk exposure using SLR maps from the National Oceanic and Atmospheric Administration (NOAA) and define "SLR risk" as being inundated in the six-foot SLR scenario by the end of 2100. We use the six-foot SLR scenario following prior literature (DeConto & Pollard, 2016; Sweet et al., 2017; Ilhan, 2021). Refer to Appendix A for more details on the construction of our SLR risk measure. The majority of loans do not originate in ZIP codes with any level of SLR risks; however, 4% of loans are located in ZIP codes with more than 20% of areas exposed to SLR risks, and the average level of inundation is 2.75%. Approximately 34% of loans are located in ZIP codes where centroids are within 30 kilometers of the coast. On average, loans are located in ZIP codes at least 245 meters above the sea level measured at the centroid. We explore the elevation level of ZIP codes for loans in coastal areas in Figure 3, which shows that the majority of ZIP codes are at least eight meters above sea level.

Figure 3: Distance to Coast & Elevation Levels



Note: The figure shows the value of loans originated by life insurers during the sample period within 30km of the coast. We plot loan values for each group by distance to coast (in kilometers) separately for the elevation level groups (in meters).

Using the Flood Insurance Rate Maps (FIRMs) from FEMA, we identify that approximately 17% of mortgages are located in ZIP codes with more than 20% of the areas mapped as SFHAs, where the annual risk of a flood is 1 in 100 or greater. Individuals and businesses with a mortgage on properties located in SFHAs from a federally backed or regulated lender are required to purchase flood insurance (Shabman et al., 2019). Although life insurers are not federally regulated, they are known to be risk-averse

lenders and most likely require flood insurance for flood-plain properties.¹¹ Since flood insurance coverage is limited to \$500,000 for a commercial property structure, we identify whether the loan size is below this limit (flood cap) for loans located in a flood-prone ZIP code (defined as a ZIP code with at least 20% of its area mapped as SFHAs). Approximately 20% of these loans are below the limit. Since FEMA maps are often criticized as being outdated or influenced by political pressure, we use another source of data to identify flood risk following recent literature (Mulder, 2022; Liao & Mulder, 2022). First Street Foundation develops its flood model considering both depth and probability of flooding due to rainfall (pluvial), riverine flooding (fluvial), and coastal surge flooding. Its flood model categorizes properties into 10 flood factors. A flood factor of 3 is considered a moderate risk in terms of both depth and frequency of flooding, and a flood factor of 10 is considered to be exposed to extreme flood risks. Refer to Appendix A for more details on the First Street Foundation data. Approximately 8% of our sample mortgages are located in ZIP codes with an average flood factor higher than 3. The average flood factor of all ZIP codes where we observe mortgages is 1.85, with the top 1% reporting a flood factor of 6.6. Lastly, using the Spatial Hazard Events and Losses Database for the United States (SHELDUS Version 20.0) database, we find that 2% of loans are located in ZIP codes that have had hurricane losses during the past two years.

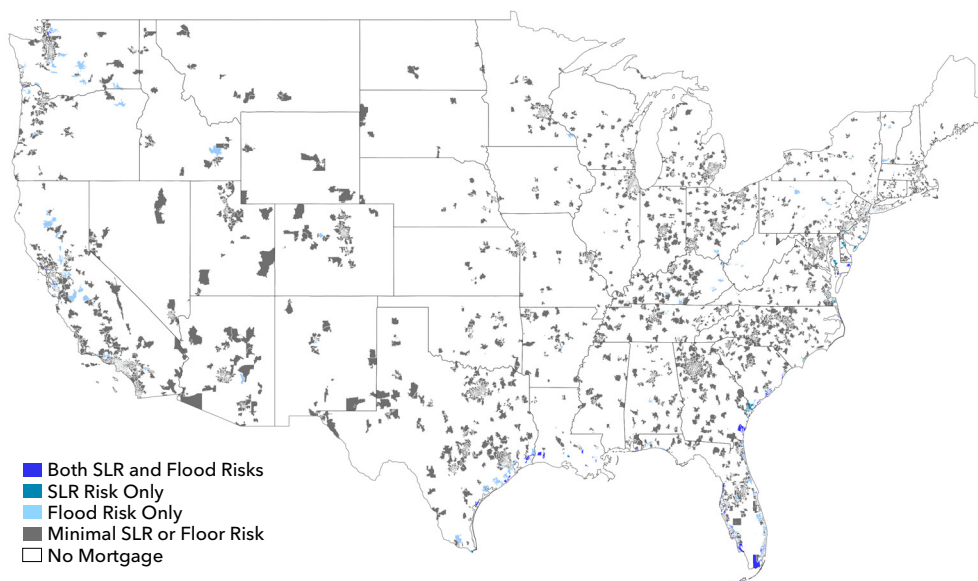
We acknowledge that the science of projecting SLR risk is constantly evolving. There has been an influx of scientific studies attempting to more accurately project SLR since the IPCC's 2007 report (Garner et al., 2018). To clarify, this paper does not endorse a specific projection of SLR by 2100. Instead, the focus of this paper is to investigate the SLR exposures of life insurers' CRE mortgage holdings, assuming that the six-foot SLR scenario materializes by 2100. The six-foot SLR assumption is commonly used in recent finance literature (Bernstein et al., 2019; Goldsmith-Pinkham et al., 2023). When it comes to flood risk measurements, the FEMA flood maps have been around for decades (with occasional updates), while the First Street Foundation flood factor data are quite new and less likely to have been used by life insurers in their decision-making. It is also possible that life insurers have access to other data enabling them to identify sources of geographical risks.

In Figure 4, we show the locations of all mortgages financed by our sample life insurers during 2012-2019. We define a ZIP code as being exposed to SLR risk if more than 20% of its area will be inundated under the six-foot SLR scenario by 2100. We define a ZIP code as being exposed to flood risk if its average flood factor is more than 3 using the First Street Foundation flood factor data. We color locations differently depending on whether the ZIP code is exposed to SLR risk or flood risk: ZIP code areas exposed to both SLR risk and flood risks are represented by dark blue shades; areas only exposed to SLR risk are represented by bright blue shades; areas only exposed to flood risk are represented by light blue shades; areas with minimal SLR or flood risk exposure, if any, are represented by gray shades; areas

11. Compliance with this flood insurance mandatory purchase requirement in the residential market is not universally enforced and compliance varies around the country, and on average closer to 50% (National Research Council, 2015; Dixon et al., 2006). Anecdotal evidence suggests that compliance among commercial properties is higher. In addition, our conversation with a commercial property broker, who services loans for life insurers, suggests that the continuous placement of flood insurance for flood-plain properties is important.

without any mortgages financed by life insurers are in white. The map shows that at the industry level, life insurers originate commercial mortgages across the U.S. We see a concentration of loans in metropolitan areas along the East Coast and the West Coast, including in high-risk areas, such as the Miami-Dade county area, the Florida Keys and San Francisco in California. Refer to Appendix B for a zoomed-in view of the southern region of the U.S.

Figure 4: Geographical SLR and Flood Risk Exposure of Life Insurer Mortgages



Note: The figure plots zip codes with at least one commercial mortgage issued by life insurers during the sample period. Only zip codes with at least one mortgage are colored. Different colors represent different levels of exposure to sea level rise (SLR) risk and/or flood risk. We define a zip code as being exposed to *SLR Risk Only* if more than 20% of its area will be inundated under the six-foot SLR scenario by 2100 but has an average flood factor no more than 3 (bright blue). We define a zip code as being exposed to *Flood Risk Only* if its average flood factor is more than 3 based on the First Street Foundation data but no more than 20% of its area will be inundated (light blue). We define a zip code as being exposed to *Both SLR and Flood Risks* if more than 20% of its area will be inundated and it has an average flood factor of more than 3 (dark blue). There were no commercial loans issued in either Alaska or Hawaii during the sample period.

In Table 2, we summarize the characteristics of our sample life insurers. By construction, these are insurers with at least three new commercial mortgages during the sample period. Our sample of 1,376 insurer-year observations (loan portfolios) includes between 149 to 184 unique insurers during the sample period (unbalanced panel data). The average size of the insurers is \$20 billion in assets, with a large standard deviation of nearly \$40 billion. Almost all insurers report high RBC ratios above the regulatory threshold of 200%, and the majority have capital levels (i.e., capital and surplus) of at least 3% of their total invested assets. On average, 11% of their assets are held in mortgages (commercial and residential combined). Most of our sample insurers belong to a group and are stock insurers. Some of them have a direct connection with a property and liability (P&L) insurer. Specifically, 16% of them share the same office with a P&L insurer, and 9% of them have a C-level executive (e.g., CEO, CIO, or CFO) who had previously held similar positions in a P&L insurer.

Table 2: Insurer-level: Summary Statistics of Life Insurers

	Obs	Mean	SD	1st	25th	50th	75th	99th
A: Firm Characteristics								
<i>Firm assets (Bil.)</i>	1,376	20.10	39.13	0.03	1.44	6.55	18.89	232.59
<i>RBC Ratio</i>	1,376	1023.98	669.70	359.70	748.65	915.93	1126.64	3338.12
<i>Capital level (%)</i>	1,376	12.99	9.42	2.52	7.19	10.02	15.17	52.84
<i>Total Mortgages/Assets</i>	1,376	0.11	0.08	0.01	0.06	0.09	0.13	0.44
<i>I(Belongs to Group)</i>	1,376	0.91	0.29	0.00	1.00	1.00	1.00	1.00
<i>I(Stock Insurer)</i>	1,376	0.90	0.29	0.00	1.00	1.00	1.00	1.00
<i>I(Same Office with P&L)</i>	1,376	0.16	0.36	0.00	0.00	0.00	0.00	1.00
<i>I(P&L Experience)</i>	1,376	0.08	0.27	0.00	0.00	0.00	0.00	1.00
B: Loan-portfolio								
<i>Number of New Loans</i>	1,376	31.19	64.51	1.00	5.00	13.00	34.00	423.00
<i>Property Type HHI</i>	1,376	0.46	0.25	0.20	0.29	0.37	0.54	1.00
<i>Avg. Loan Value (Mil.)</i>	1,376	15.78	26.21	0.05	2.68	7.01	18.20	140.93
<i>Avg. Spread</i>	1,376	2.41	1.40	0.60	1.71	2.05	2.66	8.57
<i>Avg. LTV</i>	1,376	0.55	0.13	0.07	0.49	0.56	0.63	0.89
<i>Avg. Loan Terms</i>	1,376	11.89	5.18	1.50	9.24	11.40	14.14	28.41
<i>Hotel/Other Share</i>	1,376	0.15	0.24	0.00	0.00	0.06	0.19	1.00
<i>SLR 20% Share</i>	1,376	0.06	0.13	0.07	0.49	0.56	0.63	0.89
<i>Flood Zone Share</i>	1,376	0.18	0.20	0.00	0.01	0.15	0.24	1.00
<i>Flood Cap Share</i>	1,376	0.09	0.26	0.00	0.00	0.00	0.00	1.00
<i>Flood Factor>3 Share</i>	1,376	0.10	0.16	0.00	0.00	0.05	0.12	1.00
<i>Hurricane past 9 qtrs Share</i>	1,376	0.02	0.08	0.00	0.00	0.00	0.00	0.38
Observations	1,376							

Note: This table reports summary statistics of firm-year level variables. *Firm assets (Bil.)* is total invested assets (i.e., general account assets) of an insurer in billions of dollars, *RBC Ratio* is the ratio between total adjusted capital and authorized control level risk based capital, *Capital level (%)* is the capital and surplus divided by total invested assets multiplied by 100, *Total Mortgages/Assets* is share of invested assets held in mortgages (year-end), *I(Belongs to Group)* is an indicator that the firm belongs to an insurance holding group, *I(Stock Insurer)* is an indicator that the firm is a stock insurer, *I(Same Office with P&L)* is an indicator that the life insurer shares the main office with a sibling P&L insurer, and *I(P&L Experience)* is an indicator that the life insurer's investment decision makers (e.g., CIO, CFO, or CEO) have had similar executive positions in a P&L insurance company (not necessarily a sibling P&L insurer). *Number of New Loans* is the number of new loans issued by the insurer in each year, *Property Type HHI* is the Herfindahl-Hirschman Index of property types (based on five property types: multifamily, retail, industrial, office, hotel and others). *Avg. Loan Value (Mil.)*, *Avg. Spread*, *Avg. LTV*, and *Avg. Loan Terms* are loan-value weighted average of loan value (in millions of dollars), interest rate spreads, LTV ratio, and loan terms (in years). *Hotel/Other Share* is the loan-value weighted share of loans in hotel or other property types. *SLR 20% Share*, *Flood Zone Share*, *Flood Cap Share*, *Flood Factor>3 Share*, and *Hurricane past nine qtrs Share* are: share of loan values in zip codes exposed to SLR risk (more than 20% of areas inundated under the six-foot SLR scenario); in flood zones (more than 20% of the zip code areas designated as SFHAs); in zip codes with an average flood risk factor of more than 3; in zip codes that experienced hurricane losses in the past 9 quarters.

We also provide insurer-level summary statistics on mortgage loan portfolios in Table 2, Panel B. While half of the insurers issue fewer than 13 loans per year, the top 25% issue more than 34 loans per year. We calculate whether an insurer concentrates on a particular property type. Specifically, we calculate a Herfindahl-Hirsch Index (HHI), which represents the concentration of loan value across five property types defined in Figure 2. The higher the HHI, the higher the concentration. An HHI value of 1 suggests

that the insurer only lends to a certain type of property. The majority of insurers have a diversified set of property types with an average HHI of 0.46. We then consider a set of geographical diversification measures and create a loan value-weighted proportion of loans in areas exposed to SLR risk (more than 20% of the ZIP code area inundated under the six-foot SLR scenario), in flood zones (any ZIP code with more than 20% of its area designated as SFHAs), in areas recently exposed to hurricanes, and in areas exposed to flood risks (ZIP codes with a flood factor higher than 3 based on the First Street Foundation data).¹² We also calculate the loan value-weighted proportion of loans with smaller than \$500,000 in loan value in flood zones, which is the coverage limit for commercial flood insurance through the NFIP (flood cap). We find that the summary statistics of these characteristics are similar to our loan-level statistics, as shown in Table 1, except for the weighted average loans that are below the flood insurance coverage limit, which is smaller after taking into account the weights of the loan value within insurers, indicating that large insurers are less likely to finance loans below the coverage limit in flood zones.

2.3. Case Studies of Insurers Highly Exposed to SLR Risk

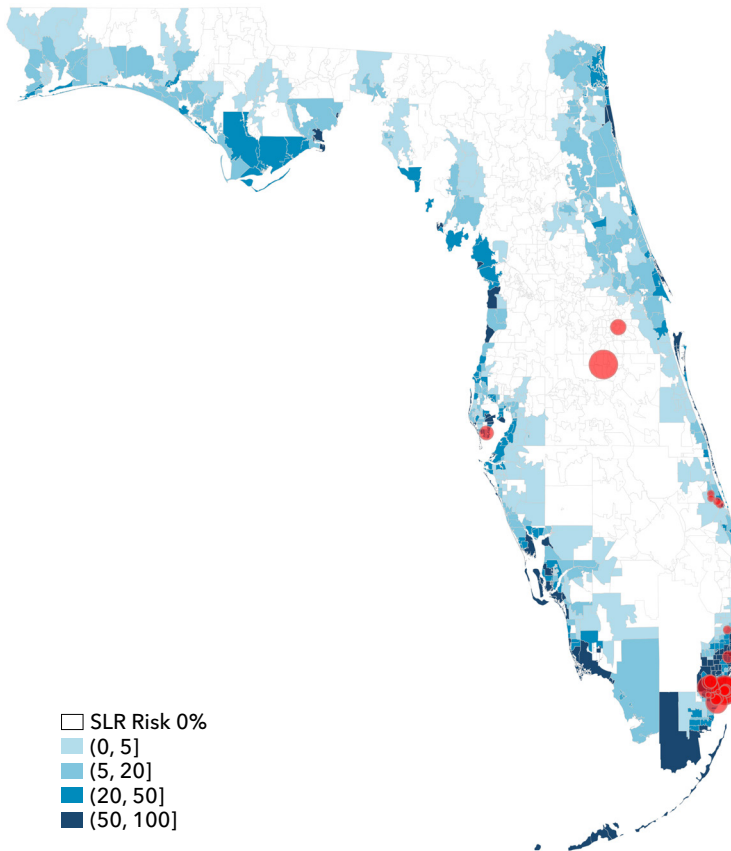
We now focus on the top three insurers most exposed to SLR risk based on their loan-value weighted exposure to SLR risk during 2012–2019. The top-ranked insurer is a small insurer with less than \$1 billion in assets; the second-ranked insurer is a medium-sized insurer with assets between \$1 billion and \$10 billion; and the third-ranked insurer is a large insurer with more than \$10 billion in assets. We follow the NAIC (2021) in categorizing small to large insurers in terms of asset size.

We plot the locations of these insurers' commercial mortgage loans in Figures 5–7, respectively.¹³ The ZIP codes in the maps are color-coded based on their levels of exposure to SLR risk. For the case study maps, we colored ZIP codes regardless of whether they had any insurer-issued commercial mortgages. We then overlay bubbles that represent the total loan values issued by the insurer per ZIP code from 2012 to 2019 in 2019 dollars (adjusted by the Consumer Price Index [CPI]).

Figure 5 shows that all of the loans originated by the insurer with less than \$1 billion in total investment size are in Florida. In addition, most loans are on the coast, with large clusters in the Miami-Dade county area. Seventy-two percent of properties (out of a total of 29 properties) are categorized as "other" by the NAIC, which includes multipurpose complexes. Most of the loans are below \$2 million, which is relatively small compared to the industry average, though not negligible given that this insurer's total assets are below \$1 billion. The largest loan originated by this insurer—at \$4.8 million—is in the Miami-Dade county area.

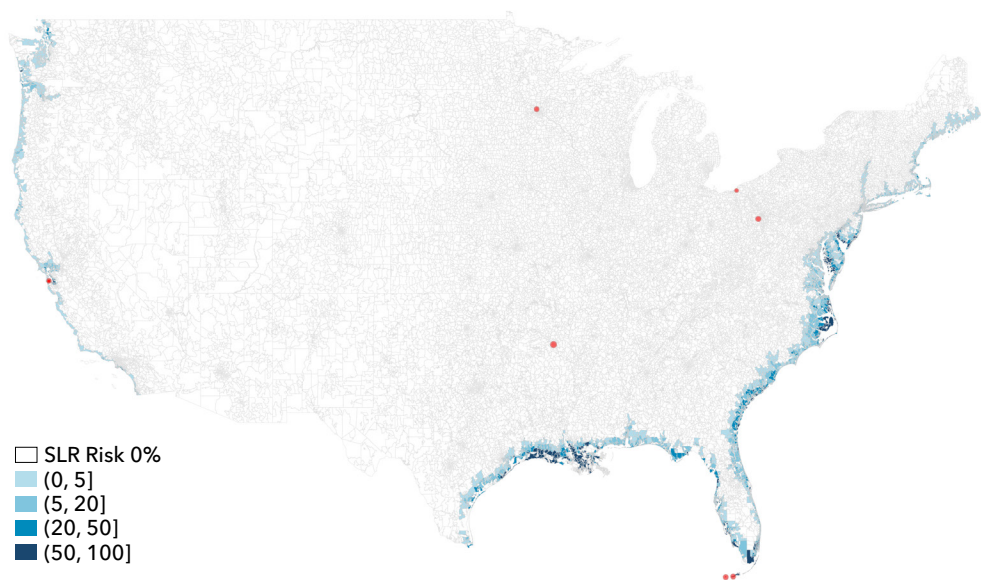
12. The distribution of these geographical diversification measures appears to be highly skewed, suggesting that a small number of insurers have relatively high exposure to SLR or flood risk. These insurers collectively represent a substantial portion of the market share in terms of total assets. For example, the 18 insurers whose mortgage portfolio SLR risks are at the top 10 percentile at the end of 2019 hold \$439 billion in total assets.

13. We show the maps of loan portfolios of top-ranked insurers in terms of flood risk (First Street Factor) in Appendix B. The characteristics of these insurers can be summarized similarly to those top-ranked insurers in terms of SLR risk.

Figure 5: Case Study - A Small Insurer with High SLR Risk Exposure

Note: The figure shows the locations of all loans issued by a small life insurer with high exposure to SLR risk. Each red bubble represents the total size of loans issued by this insurer during the sample period in a particular zip code. Larger bubbles represent larger loan values. The colors of the zip codes represent different percentages of areas that will be inundated under the six-foot SLR scenario by 2100.

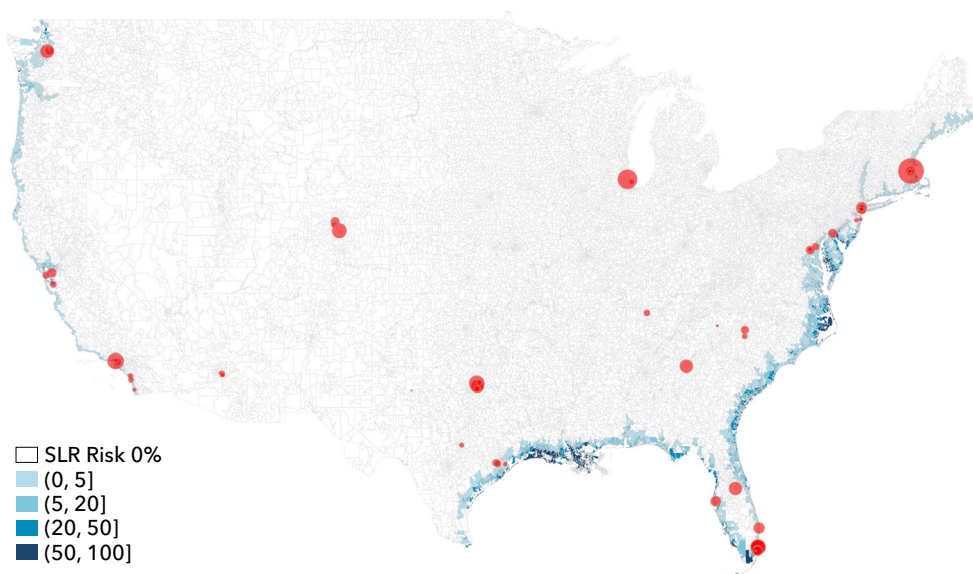
We show a similar map for the mid-sized insurer between \$1 billion and \$10 billion in total investment size in Figure 6. This insurer issued loans across the U.S., in both inland and coastal areas, including in the Florida Keys, one of the areas with the highest SLR risk. The bubble sizes are similar across the U.S., suggesting that loan values are relatively equally distributed across areas. The average loan size for this insurer is about \$20 million.

Figure 6: Case Study – A Mid-size Insurer with High SLR Risk Exposure

Note: The figure shows the locations of all loans issued by a mid-sized life insurer with high exposure to SLR risk. Each red bubble represents the total size of loans issued by this insurer during the sample period in a particular zip code. Larger bubbles represent larger loan values. The colors of the zip codes represent different percentages of areas that will be inundated under the six-foot SLR scenario by 2100.

Figure 7 shows the locations of loans originated by the insurer with more than \$10 billion in total investment size. We find that this insurer also issued loans in a diversified set of metropolitan areas in the U.S., including many on the coast. Moreover, this insurer issued larger-sized loans in coastal areas like Florida and Massachusetts than in inland areas like northern Texas or Tennessee. The average loan size of this firm is \$7 million, with loans ranging from \$60,000 to \$70 million in size. Some of the large loans include one at \$25 million in Miami-Dade county and one at \$70 million in coastal Massachusetts.

The commercial mortgage lending patterns of these three insurers provide insights into how a small insurer can be highly exposed to climate change risk by concentrating lending activities on a region highly prone to flood or SLR risks and how modest to large-sized insurers can also be exposed to such risks by issuing large loans in coastal areas even though they hold geographically diversified loan portfolios.

Figure 7: Case Study - A Large Insurer with High SLR Risk Exposure

Note: The figure shows the locations of all loans issued by a large life insurer with high exposure to SLR risk. Each red bubble represents the total size of loans issued by this insurer during the sample period in a particular zip code. Larger bubbles represent larger loan values. The colors of the zip codes represent different percentages of areas that will be inundated under the six-foot SLR scenario by 2100.

3. Regulatory Reforms

In recent years, two regulations relevant to life insurers' perceptions of climate change risk—especially those related to SLR and flood risks—and their commercial mortgage finance decisions went into effect. First is the regulatory capital rule that changed how RBC charges are calculated for holding commercial mortgages. Second is BW-12, which started the phasing out of subsidies and discounts on flood insurance premiums. Both of these regulations went into effect around the beginning of 2014.

3.1. Commercial Mortgage RBC Reform

One of the tools regulators use to monitor life insurers' capital adequacy levels is the RBC ratio, which is the ratio between total capital adjusted for regulatory purposes and RBC. RBC is calculated separately for insurers' investment risk, insurance risk, interest rate risk, and business risk. When it comes to investment risk, RBC is the value of the investments multiplied by the RBC charges defined by the state insurance regulators for different asset classes. Traditionally, RBC charges for commercial mortgages in good standing (i.e., defined as interest payment not overdue) were 0.1% if they were insured or guaranteed and 1.3% if not. RBC charges for commercial mortgages not in good standing (i.e., defined as either overdue or in the process of foreclosure) ranged between 0.2% to 17%. The majority of commercial mortgages are in good standing

without insurance/guarantee,¹⁴ and the RBC charges were commensurate to those for an investment-grade corporate bond (0.9%). At the company level, the mortgage experience adjustment factor for commercial mortgages in good standing was also part of the RBC calculations; however, the factor was calculated at the portfolio level (i.e., loss ratios of all commercial mortgages in good standing held by a company) and its relative ratio to that of the industry mortgage experience adjustment factor was included in the RBC calculation.

At the end of 2013, the RBC charge for commercial mortgages in good standing without insurance/guarantee was updated, and a granular breakdown of the RBC charges for different categories of commercial mortgages was put into place. Consequentially, the RBC charges no longer include company-level mortgage experience adjustment factors. Five categories of commercial mortgages in good standing without insurance/guarantee were created, with the highest quality (CM1 category) facing a 0.9% RBC charge and the lowest quality (CM5 category) facing a 7.5% RBC charge. The five categories are defined based on the debt service coverage (DSC) ratio and loan to value (LTV) ratio. DSC is the ratio of net operating income to standardized debt service (calculated by amortizing the loan's principal balance at the RBC calculation date over a standard 25-year period at the contract interest rate). LTV is defined as the current principal balance to a contemporaneous property value, taking into account the change in property value since the origination date based on the most recent publication value of the National Council of Real Estate Investment Fiduciaries (NCREIF) Real Property Price Index. Each loan is bucketed into one of the five categories based on the combination of its DSC, LTV, and property type. The charges are higher for hotels or other properties than other common types of commercial properties, such as multi-family, office, retail, and industrial buildings.

3.2. The Federal Biggert-Waters Flood Insurance Reform Act of 2012

The NFIP, run by FEMA, offers flood insurance to both residents and businesses. FEMA is also in charge of providing communities with FIRMs, which delineate the SFHAs where flood insurance is required for a mortgage from a federally backed or regulated lender, including life insurers. Lenders of commercial properties often require supplemental excess flood insurance for coverages above the NFIP limit (Real Estate Roundtable, 2023). Flood insurance prices are based primarily on the location of the property (e.g., if it is in an SFHA) and whether the property was built before or after the community's first FIRM went into effect.

For properties built before the community was mapped, flood insurance premiums were subsidized since the property owners (individuals and businesses) may not have been aware of flood risk when they built or purchased the property. The federal Biggert-Waters Flood Insurance Reform Act of 2012 (BW-12) calls for the phase-out of subsidies and discounts on flood insurance premiums. Starting on Oct. 1, 2013, owners of commercial (business) properties with subsidized premiums faced up to a 25% increase in premium rates each year until premiums reflected full risk rates

14. The majority of commercial mortgages are not insured/guaranteed, as the NAIC defines insured/guaranteed mortgages as those backed up by government entities (e.g., Federal Housing Administration, Veterans' Administration, or National Housing Act of Canada). Such insured/guaranteed status applies to most residential mortgages, which are not in the scope of this paper.

(FEMA, 2013). As the implementation of BW-12 began, the resulting premium increases became a focus of intense political and public attention. Many communities argue that the premium increases were unaffordable. In response, Congress passed the federal Homeowner Flood Insurance Affordability Act of 2014 (HFIAA 2014), which either delayed or capped the annual premium increases for primary residences. Non-primary residences or commercial properties were not affected by HFIAA 2014 and would follow the premium increase schedules in BW12.¹⁵

The NFIP underwrites about five million policies per year, and 5%-7% are policies on commercial properties. This statistic varies across regions. An overview of the NFIP in Washington, DC, (Kousky & Shabman, 2021) shows that as of 2021, most NFIP claims in Washington, DC have been for commercial properties. In terms of premiums, about 20% of the total number of NFIP policies received subsidies before the BW-12, while 30%-40% of commercial properties received subsidies, indicating that the effect of BW-12 may be more pronounced for commercial properties than for residential properties.

The existing literature that examines the effect of BW-12 predominantly focuses on the residential real estate market and finds mixed results. Most of this literature does not find any significant effect of this reform on the residential market (Gibson & Mullins, 2020; Bakkensen & Barrage, 2021; Hino & Burke, 2021). A few recent working papers, though, find some effect of this reform on the residential market, either in terms of a lower LTV ratio (Sastry, 2022) or in terms of lower property prices for those on the flood plains (Ge et al., 2022).

3.3. Impacts of the Reforms on Mortgage Portfolios

In this section, we focus on identifying whether the regulatory reforms affect insurers' commercial mortgage portfolios with respect to flooding and SLR risk exposure. To the best of our knowledge, there is no empirical research identifying the effect of either the RBC charge reform or BW-12 on the commercial mortgage market.

The flood insurance reform has increased flood insurance premiums for many commercial property borrowers since late 2013. The RBC charge reform incentivizes insurers to originate safer loans with lower LTV ratios, which may affect insurers' decisions to finance properties exposed to SLR risk because deteriorating property value can increase LTV ratios, which will increase the RBC risk charge for insurers. Due to the above reasons, life insurers may reduce lending in risky areas after 2014.

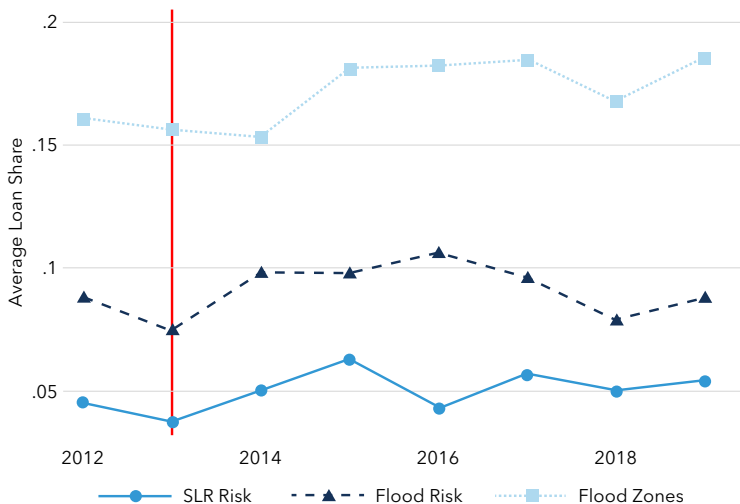
On the other hand, it is also possible that most of the borrowers have the capacity to pay for the increased flood insurance premiums or that the NFIP flood insurance is not a binding constraint due to the low structural coverage limit (\$500,000). In addition, life insurers could factor in the increased RBC risks when pricing mortgages, e.g., by charging higher interest payments or by requiring higher down payments from the borrowers, i.e., reducing the LTV ratios per loan. These possibilities lead to an alternative hypothesis where we do not observe a decline in life insurers' exposure to flood or SLR risks but instead see increased interest rates or decreased LTV ratios. Although this alternative hypothesis is possible, we refrain from studying the loan

15. Effective 2021, NFIP adopted a new risk rating system that affects the pricing of flood insurance for new policies (FEMA, 2021). Given that our study period is 2012 - 2019, we do not consider this change in our analysis.

underwriting decisions in this paper for two reasons. First, such analysis requires using detailed street-level addresses and additional loan information (e.g., net operating income or DSC ratio) to measure the accurate SLR risk or flood risk (Grovenstein et al., 2005; Harrison et al., 2004; Titman et al., 2005). We do not have access to such granular information, which can bias our findings. Second, the main goal of this study is to understand insurer-level climate change risk exposure. We consider the alternative hypothesis related to loan-level characteristics as a future study.

In Figure 8, we show the yearly trend of the average share of loans located in ZIP code areas characterized by: 1) relatively high exposure to SLR risk (blue circles), defined as any ZIP code with more than 20% of its areas being inundated under the six-foot SLR scenario;¹⁶ 2) a relatively high proportion of flood zones (dark blue squares), defined as any ZIP code with more than 20% of its areas designated as SFHAs; and 3) a relatively high flood factor (light blue triangles), defined as any ZIP code with a flood factor higher than 3. Given that we are interested in how life insurers' mortgage portfolios change over time due to the regulatory reforms, we present the average share of risks per insurer-level mortgage portfolio. We weight each loan by the value of the loans when calculating the insurer-year level shares in different risk areas. Over our sample period, we find that on average, 4%–5% of the commercial loans originated by life insurers are in areas with relatively high SLR risk exposure; 15%–18% are in areas with a relatively high proportion of flood zones; and 8%–10% of commercial loans are in areas with a moderate level of flood risks. Figure 8 suggests that there was no significant decline in SLR or flood risk exposure at the insurer level around 2014 (highlighted with a red vertical line in 2013) when the regulatory reforms took place.

Figure 8: Insurer-level Risk Exposure



Note: This table reports the average risk exposure by terciles of insurers in terms of RBC ratios (ranked from the lowest to the highest) and size measured by total invested assets (ranked from the lowest to the highest), separately for Pre

16. We tested the sensitivity of the SLR risk exposure thresholds using 10%, 30%, and 50%. There are slightly more ZIP-code areas inundated if we use the 10% threshold and vice versa if we use the 30% or 50%, but the overall takeaway was similar.

(2012-2013) and Post the reform (2014 and after). Terciles are calculated separately each year using sample insurers. For each insurer, we calculate the share of loan values in A. zip codes exposed to SLR risks; B. zip codes exposed to flood risks; and C. zip codes with more than 20% of the area designated as SFHAs. We report statistics of equality of the means between the periods for each tercile groups in column "Diff". These are estimated assuming unequal variance structure across periods. *p < 0.1, ** p < 0.05, *** p < 0.01.

We conjecture that the stable trend represents the overall pattern in the life insurance industry, yet there could be heterogeneity across insurers. We are particularly interested in the RBC ratios and the size of insurers. The RBC reform can affect insurers with low RBC ratios differently than those with high RBC ratios. Larger insurers (in terms of total invested assets) may have more capacity to take on risk due to their ability to diversify internally. Table 3 tabulates the association between insurer characteristics and risk exposures. We create three equally sized bins of insurers (terciles) in terms of their RBC ratios and sizes (total investments) in each year. Tercile 1 refers to the group with the lowest RBC ratio or the smallest in size, while Tercile 3 refers to the group with the highest RBC ratio or the largest in size. In Panel A, we show the differences in SLR risk exposure across insurers with different RBC ratios and sizes and tabulate them separately for periods before the reform (2012-2013) and periods after the reform (2014-2019). We show the differences in flood zone exposure in Panel B and the differences in flood risk exposure based on First Street Foundation's average flood factor in Panel C. We also report mean differences and t-test statistics showing whether there is a significant difference in risk exposure before and after the reforms around 2014 for insurers belonging to different tercile groups.

Table 3: Risk Exposure by RBC Ratios and Size

Terciles by	RBC Ratio			Size		
	Pre	Post	Diff	Pre	Post	Diff
A. SLR Risk Exposure						
1	0.051	0.057	0.007	0.047	0.040	-0.007
2	0.045	0.056	0.010	0.053	0.054	0.001
3	0.063	0.058	-0.005	0.059	0.078	0.049*
B. Flood Risk Exposure						
1	0.084	0.106	0.022	0.088	0.097	0.008
2	0.094	0.104	0.010	0.080	0.097	0.017
3	0.079	0.089	0.010	0.089	0.105	0.016*
C. Flood Zone Exposure						
1	0.187	0.200	0.012	0.182	0.209	0.026
2	0.159	0.186	0.027	0.151	0.166	0.015
3	0.146	0.169	0.023	0.160	0.181	0.021

Note: This table reports the average risk exposure by terciles of insurers in terms of RBC ratios (ranked from the lowest to the highest) and size measured by total invested assets (ranked from the lowest to the highest), separately for Pre (2012-2013) and Post the reform (2014 and after). Terciles are calculated separately each year using sample insurers. For each insurer, we calculate the share of loan values in A. zip codes exposed to SLR risks; B. zip codes exposed to flood risks; and C. zip codes with more than 20% of the area designated as SFHAs. We report statistics of equality of the means between the periods for each tercile groups in column "Diff". These are estimated assuming unequal variance structure across periods. *p < 0.1, ** p < 0.05, *** p < 0.01.

Overall and consistent with the industry-level trend in Figure 8, we do not find significant changes in SLR or flood risk exposures after 2014. The only exception is for the largest group of insurers, where they increased their mortgage loan exposures to SLR and flood risks, seemingly contrary to the intention of the reforms. In terms of risk exposure differences across insurers in different terciles of RBC ratio or size, larger insurers are more exposed to SLR risk and flood risk in their mortgage loan portfolios, while insurers with higher RBC ratios are less exposed to the FEMA-designated flood zone. Our analysis, however, does not consider possible changes in loan interest rate spread or other loan characteristics, such as LTV ratios, due to data limitations.

4. Conclusion and Regulatory Implications

In this paper, we analyze the commercial mortgage portfolios of life insurers and, in particular, focus on their exposures to SLR risk and flood risk. We find significant heterogeneity in loan locations across insurers, as well as in the insurer-level risk exposure. We do not find significant changes in insurer-level exposure to SLR or flood risks before and after the commercial mortgage RBC reform or BW-12 around 2014. A couple of measurement errors are inherent in this study due to the limited reporting requirement in the statutory statements. Life insurers do not report street-level addresses (the most micro-level geographical information available is the ZIP-code level), which is crucial to identifying accurate property-level exposure to SLR or flood risk. We also do not observe loan-level net operating income or DSC ratios. With the increasing risk of climate change, regulators should consider requiring more detailed geographical and financial information from insurers to identify the physical and transition risks in their commercial mortgage loan portfolios. The goal of this work is to identify patterns in commercial mortgage lending across insurers using ZIP code as a location proxy to inform regulators who monitor insurer-level solvency risks. With better data on location and loan-level characteristics, future work could focus on further disentangling the mechanisms through which SLR or flood risk is priced by insurers, as well as whether and how insurer characteristics influence commercial mortgage underwriting decisions in climate risk-prone areas.

Appendix A Data

A.1 Life Insurer Data: Commercial Mortgage Loan-level Characteristics

We obtain data on CRE mortgages originated by life insurers from their annual statutory statements filed through the National Association of Insurance Commissioners (NAIC). Specifically, Schedule B Part 2 of the statutory statements reports loans originated during that year and includes the following loan characteristics: a unique loan identification number, interest rate, book value, appraisal value, acquisition date, maturity date, property type, and property location at the zip code level.¹⁷

Our sample loans are originated by active stock or mutual life insurers with positive invested assets during 2012 - 2019. Property location information at the zip code level is only available for loans originated from 2014 onward. For the period before 2014, we impute zipcode level location information using life insurers' year-end holding data from 2014 to 2019, following Glancy et al. (2019).¹⁸ We follow Glancy et al. (2019) to identify whether a loan is a fixed or floating rate loan using each loan's interest rate history from the holdings data. Approximately 90% of loans are observed for at least two years in the holdings data, enabling us to identify fixed versus floating rate loans. We focus on fixed-rate loans, for which an interest rate spread can be calculated in a consistent manner. We include loans with a minimum of \$100k loan values and complete loan-level information. Loans with values smaller than \$100k are mostly additional loans. We drop loans with multiple zip codes associated with them since having multiple zip codes compromises our ability to accurately match a loan with a host of location information.¹⁹ We also drop loans associated with zip codes for which there is no geographic information (possible reasons are special addresses or P.O. boxes).

A.2 Life Insurer Data: Insurer-level Characteristics

Insurer characteristics of sample insurers that originate CRE mortgages are also taken from the NAIC annual statements. These include the size of the firm (total invested assets), regulatory capital levels measured by the Risk Based Capital (RBC) ratio, capital to asset ratio, the share of assets in mortgages, concentration of commercial mortgages compared to other types of mortgages, organizational form (stock insurer indicator), and an indicator of belonging to an insurance holding group. In addition, some life insurers can be connected with Property & Liability (P&L) insurers -who specialize in underwriting and pricing property risks - through sharing a same location (when they both belong to an insurance holding group) or some key employees.

17. Some loans reported in Schedule B Part 2 share the same loan identification number with other loans reported earlier by the same insurer, i.e., any increases or additions to mortgage loans acquired in prior periods are recorded by life insurers in the same schedule. We refer to these loans as "additional" loans. Property type includes multifamily, office, industrial, retail, and others (including hotels, medical buildings, and mixed purpose buildings).

18. Each insurer applies a unique loan identification number to each loan, enabling us to track loan information from 2014 onwards. Loans originated before 2014 are imputed with property zipcode and type information in the holdings data during 2014 - 2020 (and sales data in 2014); for 2012 loans, we retain 80% of the loans with zipcode information and it is 94% for 2013 loans.

19. 5.5% of loans have multiple zip codes, e.g., a mortgage loan is associated with properties covering multiple cities over multiple states. In such a case, insurers are required to list the zip codes in descending order of the loan size. However, no information is available on loan size corresponding to each zip code.

These “P&L connected” life insurers may have better knowledge and expertise in the CRE mortgage market. We identify a life insurer’s connection to any P&L insurer in two ways: one, whether a life insurer shares a main office location with a sibling P&L insurer that belongs to the same insurance holding group; two, whether a life insurer’s investment decision makers (CIO, CFO, or CEO) have held a similar position in any P&L insurance company before (regardless of being within the same insurance group).

A.3 Sea Level Rise Risk Data

We obtain SLR maps from the National Oceanic and Atmospheric Administration (NOAA)’s SLR Viewer tool.²⁰ NOAA provides maps of projected sea level rise to 10 feet above average high tides with 1-foot increments for the entire U.S. except Alaska. These inundation maps show the regions projected to be underwater given a certain SLR scenario by the end of 2100 and are agnostic about what the actual SLR will be at that time. We follow other finance and economic literature and choose a six-foot SLR scenario, which is also in line with recent scientific literature’s upper bound projections (DeConto & Pollard, 2016; Sweet et al., 2017). We then intersect SLR maps with zip code boundaries. Following Ilhan (2021), we use zero-feet SLR maps to identify existing water areas. For each zip-code, we calculate the difference in percent areas covered by water between those under a six-foot SLR scenario and a zero-feet scenario; the resulting variable measures zip code level SLR risk exposure.

A.4 Flood Risk Factor Data

We use the publicly available zip code level flood risk exposure data created by the First Street Foundation (FSF). Through the partnership with industry and academic experts, FSF creates a high resolution flood model per individual property level in the continental U.S. The flood model is based on scientific methods that estimate future risk of flood taking into account potential sea level rise risk, cyclonic activity, precipitation patterns, and river discharges. The model also incorporates adaptation measures. Then, for each property, a flood factor ranging from 1 (minimal) to 10 (extreme) was assigned based on an annualized expectation of flood calculated using the depth of flood and the 30-year cumulative probability of flood. We observe the number of properties exposed in each of the flood factor categories within each zip code. We create an average flood factor of the zip code by calculating the weighted average flood factor using the number of properties in each category and total number of properties in the zip code, which are also reported in the FSF dataset. See <https://firststreet.org/methodology/> for the methodology published on the FSF website.

A.5 Flood Zone Data

We download flood maps from the FEMA Flood Map Service Center.²¹ We extract information on Special Flood Hazard Area (SFHA) from the National Flood Hazard Layer geodata and overlay it with zip code boundaries to identify the percentage of areas in a zip code that is SFHA. An area is designated as SFHA if it has at least a 1% annual probability of being flooded. Flood insurance coverage is mandatory for properties

20. <https://coast.noaa.gov/slrdata/>. Accessed on February 19, 2022.

21. <https://msc.fema.gov/portal/advanceSearch>. Accessed on May 24, 2022. This is a living database and flood maps are continuously updated.

in SFHAs if they have mortgages with a federally regulated lender or are backed by the federal government (NFIP, 2021). The National Flood Insurance Program (NFIP)'s General Property Form offers commercial policyholders up to \$500,000 in building property coverage and up to \$500,000 in personal property coverage. There is no NFIP coverage for business interruption or extra expense. Some private insurance companies offer commercial flood insurance which include business interruption and extra expense. There is no requirement to get the more comprehensive private flood insurance if a property is located in an SFHA. We use the zip code level SFHA% information as a proxy for flood insurance coverage.

A.6 Hurricane Loss Data

We obtain county level major hurricane loss data from the Spatial Hazard Events and Losses Database for the United States (SHELDUS Version 20.0) from Arizona State University. For each loan, we identify whether its zip code belongs to counties that experienced property damages due to a hurricane or tropical storm.

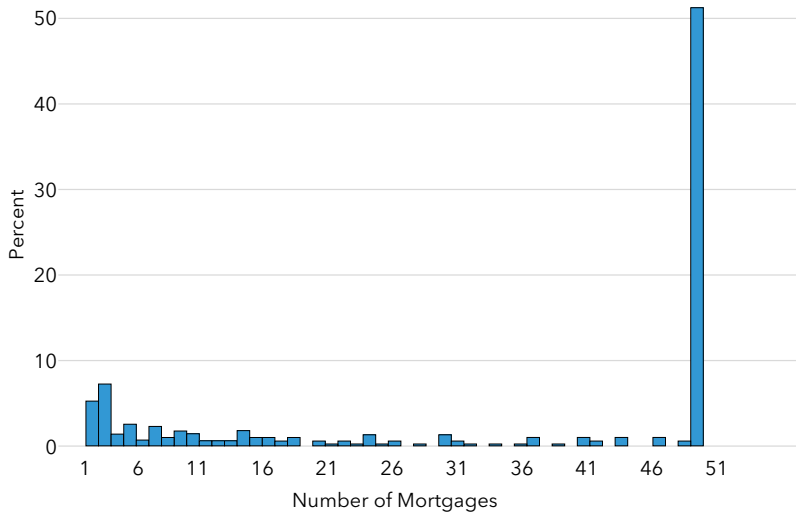
A.7 Other Location Data

We obtain distance-to-coast data come from NASA's Ocean Biology Processing Group (OBPG). The distance-to-coast spatial file comes in 0.01-degree (approximately 1.1km by 1.1km) resolution. We calculate a distance-to-coast value (km) for the population centroid of each zip code by bilinear interpolation from the NASA OBPG file.

We use the Global Multi-resolution Terrain Elevation Data 2010 (GMTED2010) from the U.S. Geological Survey (USGS) to extract the median elevation (in meters) within a 7.5-arc-second grid cell (about 250m by 250m). We then identify an elevation value (in meters) for the population centroid of each zip code.

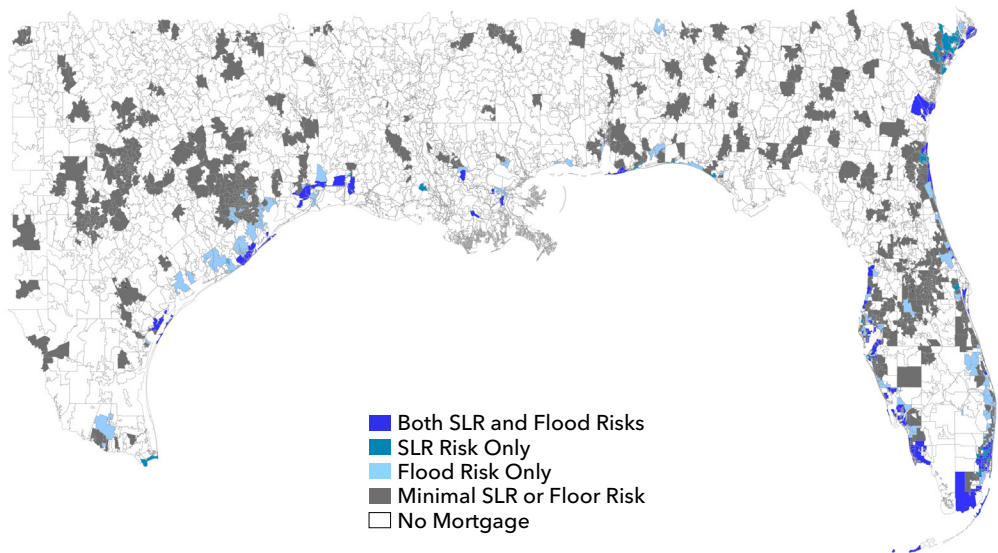
Appendix B Supplementary Figures

Figure B.1: Total Sample Mortgages Issued by Insurers



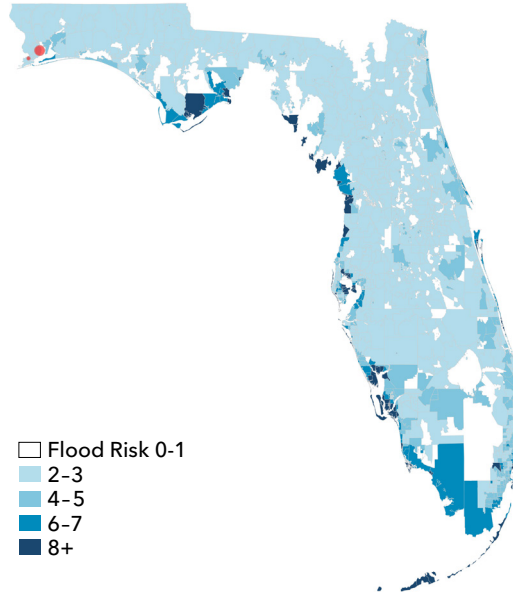
Note: The figure shows the distribution of total number of sample mortgages issued by life insurers (total 260 unique sample insurers that hold at least one sample loan) throughout the sample period. The last bar includes all insurers originating more than 50 sample loans.

Figure B.2: Geographical SLR and Flood Risk Exposure in South



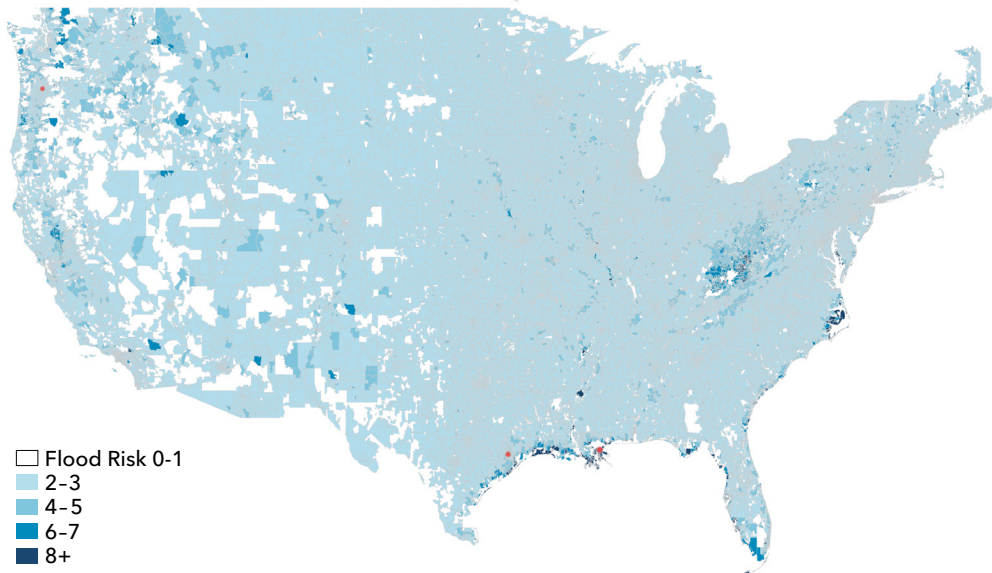
Note: The figure plots zip codes with commercial mortgages financed by life insurers during the sample period in southern parts of the U.S. near the coast, i.e., parts of Alabama, Georgia, Florida, Louisiana, Mississippi, and Texas. Different colors represent different level of sea level rise (SLR) risk and flood exposure. We define a zip code to be exposed to SLR risk if more than 20% of the zip code is exposed to SLR risks and a zip code to be exposed to flood risk if the average flood factor is greater than 3.

Figure B.3: Case Study - A Small Insurer with High Flood Risk Exposure



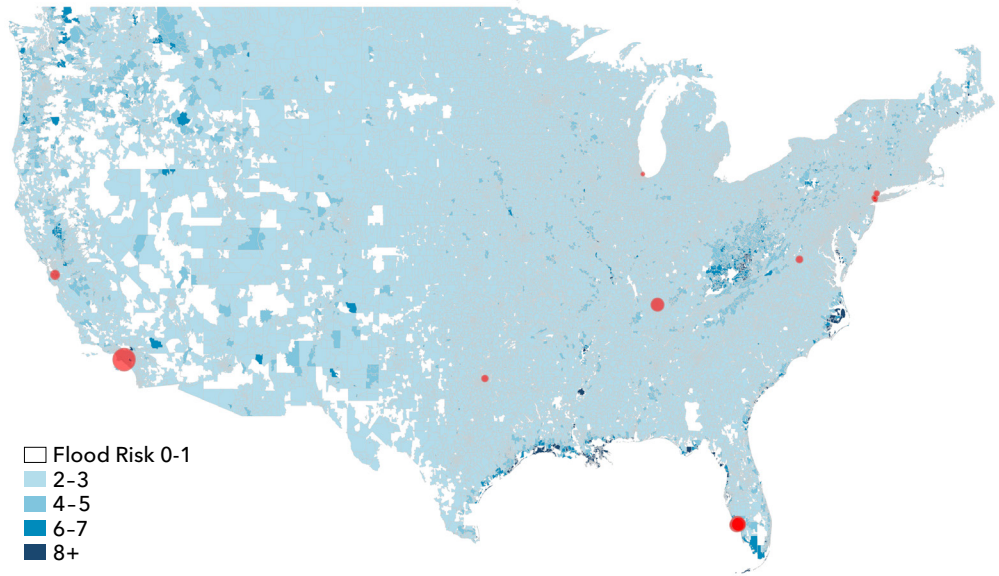
Note: The figure shows the locations of all loans issued by a small life insurer with high exposure to flood risk. Each red bubble represents the total size of loans issued by this insurer during the sample period in a particular zip code. Larger bubbles represent larger loan values. The colors of the zip codes represent different values of average flood factors.

Figure B.4: Case Study - A Mid-size Insurer with High Flood Risk Exposure



Note: The figure shows the locations of all loans issued by a mid-sized life insurer with high exposure to flood risk. Each red bubble represents the total size of loans issued by this insurer during the sample period in a particular zip code. Larger bubbles represent larger loan values. The colors of the zip codes represent different values of average flood factors.

Figure B.5: Case Study - A Large Insurer with High Flood Risk Exposure



Note: The figure shows the locations of all loans issued by a large life insurer with high exposure to flood risk. Each red bubble represents the total size of loans issued by this insurer during the sample period in a particular zip code. Larger bubbles represent larger loan values. The colors of the zip codes represent different values of average flood factors.

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